Towards effective management: toxicity, causal mechanism and controlling strategy of toxic rangeland weeds in western China

Wei He [A], Yongmei Liu [B], Hao Lu [C], Baoyu Zhao [D], Chonghui Mo [E], Juying Wu [F], Nengtai Da [G] and Yahui Wei [H]

[A] Department of Biology, Northwest University, People's Republic of China www.nwu.edu.cn
[B] Department of Urban and Environmental Science, Northwest University, People's Republic of China www.nwu.edu.cn
[C] Department of Veterinary Science, Northwest A & F University, People's Republic of China www.nwsuaf.edu.cn
[D] Qinghai University, People;s Republic of China www.qhu.edu.cn
[E] Beijing R & D Centre for Grass and Environment, Beijing Academy of Agriculture and Forestry Sciences, China www.baafs.net.cn/
[F] Veterinary Centre of Alxa (Inner Mongolia), China
Contact email: weihebio@nwu.edu.cn

Keywords: Pasture, locoweed, toxicity study, mechanism of occurrence, weed control, multi-disciplinary means.

Introduction

Toxic rangeland weeds (TRWs) pose a great threat to animal husbandry. Currently, an estimated 33 million hectares of pasture (10%) in western China is infested by a variety of toxic weeds, including *Stellera chamaejasme*, *Oxytropis* spp., *Astragalus* spp., *Achnatherum inebrians*. The spread of these toxic weeds results in huge annual economic losses of more than $2.4 billion USD (direct and indirect). A combination of ecology, molecular biology, biochemistry and field practise methods will be used to identify and evaluate TRWs, explore the mechanism of toxicity, and more importantly, understand the causal mechanism by which TRWs flourish. The knowledge will underpin the development of effective management strategies.

Methods

Identification of TRWs and the mechanism of toxicity

Field surveys were carried out in 5 provinces in western China to identify weed varieties that are toxic to livestock. Mass spectrometry was employed to identify compounds from *Oxytropis* spp. and *Astragalus* spp. which are toxic to livestock. Endophytic fungi were isolated and tested for their roles in producing the toxic compounds.

Evaluation of TRWs

Remote sensing techniques were used to evaluate the size and density of toxic weed infestations. Reflectance spectra of toxic grass varieties were acquired, and an NDVI (Normalized Difference Vegetation Index) model was built to discriminate them from other grasses based on remote sensing images. Area and distribution of toxic weeds in a certain range were then calculated.

Genetic analysis of TRWs

Oxytropis ochrocephala is extensively distributed in all the provinces in western China, and AFLP markers are being developed to understand the reproduction pattern of TRWs, tracking their origins, how they have been distributed, and predict their potential distribution.

Toxic weeds & soil biota, allelopathy effect and photosynthesis efficiency

Interactions between plants and soil biota have been reported as a measure by which plants gain advantages against competitors. Mesocosm experiments combined with field studies are being performed according to Callaway and Aschehoug (2000) and Callaway *et al*. (2004) to evaluate potential for allelopathy or photosynthetic efficiency as mechanisms for TRWs to outperform forage grass varieties.

Field practice and biological control

Effect of silage of TRWs for detoxification was tested. A slow-release detoxification pill was developed and its efficacy was tested by oral administration to livestock. Surveys were also conducted for biological control agents for toxic weeds on natural rangelands.

Results and Discussion

330 species of TRWs were identified in field surveys, among which the most widely spread species are *Stellera chamaejasme*, *Oxytropis* spp., *Astragalus* spp. and *Achnatherum inebrians*. 13 species caused severe toxicity to livestock, including nine *Oxytropis* spp., three *Astragalus* spp. and *A. inebrians*. An indolizidine alkaloid - swainsonine - was isolated from these *Oxytropis* and *Astragalus* species, and is responsible for toxic effects. Two endophytic fungi, FS-5 and EFG-7, were isolated and proven to produce swainsonine (Lu *et al*. 2012). ITS sequencing revealed that they were most closely related to *Schizophyllum* sp and *Fusarium tricinctum*, respectively. The relationship between endophyte and swainsonine provides an opportunity to manage the toxicity by suppressing the related endophyte.

Using remote sensing, a model was successfully built to identify the distribution and density of *S. chamaejasme*

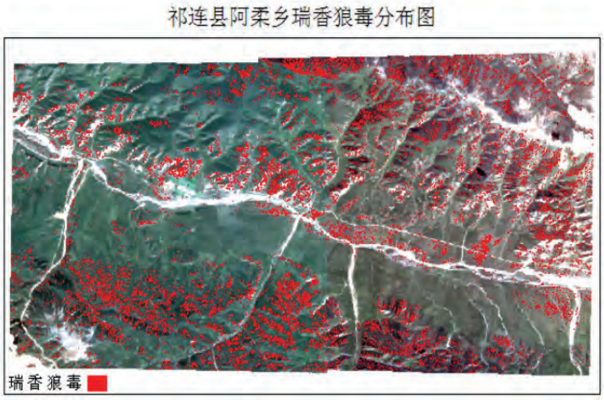

Figure 1. Distribution of *S. chamaejasme* in Qilian County (N 37°25′- 39°05′, E 98°05′- 101° 02′), Qinghai Province in China. Distribution extracted from ARCGIS and ERDAS software by Normalized Difference Vegetation Index model. Multispectral data was acquired by GEOEYE (IKONOS-2 4m). The image represents IKONOS 321 (RGB). Red spots indicate area infected by *S. chamaejasme*.

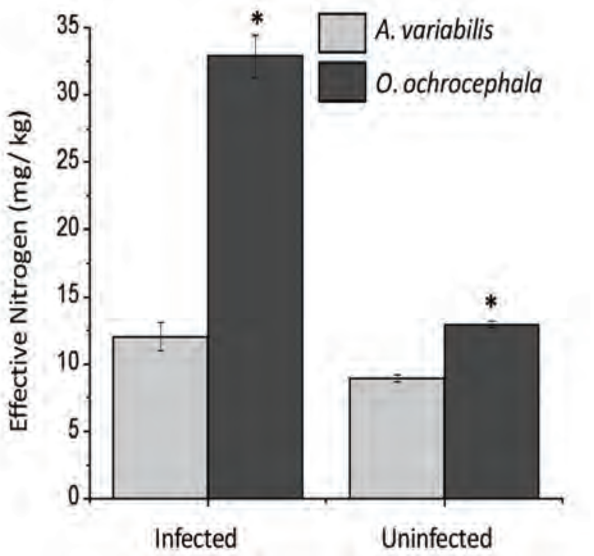

Figure 2. Effective nitrogen content (mg/ kg) in soil infected by A. variabilis and O. ochrocephala and uninfected nature pasture. Error bars indicate standard error of the mean (n=10). Asterisks indicate significant variation (*P*<0.05)

(Fig. 1). Models for other toxic weeds are being developed at present and will reduce the field work required to map the distribution of TRWs. Satellite images for such analysis should be acquired at the flowering stage for easier discrimination of TRWs from other grass species.

Soil analyses showed that the effective nitrogen content is significant higher ($P<0.05$) where *O. ochrocephala* is present (Fig. 2). Nitrogen levels were also elevated when *A. variabilis* was present, but was not statistically significant ($P=0.054$). This implies that *O. ochrocephala* can change soil properties via interactions with soil biota, possibly by increasing soil effective nitrogen to facilitate its spread. The above hypothesis needs to be tested by growing *O. ochrocephala* in soil with higher effective nitrogen content.

Swainsonine could not be detected from toxic *Oxytropis* and *Astragalus* species after the silage treatment, which provides an opportunity to use these protein rich legume species as animal feeds. The slow-release detoxification pill reduced toxicity to livestock to some extent but needs further improvement.

A worm species was found to inhabit 75 out of 100 *A. variabilis* plants in Inner Mongolia of China. The worm, yet to be taxonomically identified, caused breakdown of the roots in 31% of the surveyed *A. variabilis* plants. However, a bird species, *Podoces hendersoni*, was observed to feed on this worm. This could offer a potential biological control opportunity of *A. variabilis*.

Conclusion

Started from 2012, this project focused on a series of analyses to improve the understanding of how and why TRWs flourish. This is fundamental to developing appropriate strategies to prevent and control TRWs. In addition to the above preliminary results, AFLP analyses, interactions between toxic weeds and soil biota, allelopathic effects and photosynthesis efficiencies are currently under investigation.

Acknowledgement

The project is funded by "Special Fund for Agro-scientific Research in the Public Interest of China 2012-2016". All the authors contribute equally to this poster paper.

References

Callaway RM, Aschehoug ET (2000) Invasive plants versus their new and old neighbours: a mechanism for exotic invasion. *Science* **290**, 521-523.

Callaway RM, Thelen GC, Rodriguez A, Holben WE (2004) Soil biota and exotic plant invasion. *Nature* **427**, 731-733

Lu H, Chen J, Lu W, Ma Y, Zhao B, Wang J (2012) Isolation and identification of swainsonine-producing fungi found in locoweeds and their rhizosphere soil. *African Journal of Microbiology Research* **6**, 4959-4969